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ABSTRACT

One area explored in the second (in-depth) phase of the Learning in Science Project was "children's science," defined as views of the world and the meanings for words that children have and bring with them to science lessons. The investigation reported focuses on the concept of "light" held by 36 students. Data were obtained during individual interviews in which students were shown cards with diagrams representing either light sources (such as candle, sun) or light reflectors (such as moon, mirror). Student responses are presented, discussed, and analyzed in separate sections representing key questions asked: (1) Does the object make light? (2) Does light travel and if so how far? and (3) How is it that the person is able to see the (candle)? Responses are categorized within each section by major patterns noted during analyses. The second question was further explored by means of surveys administered to Form 2 (N=144) and Form 3 (N=235) students. Implications for science instruction, based on such findings as few students understanding that light must travel into the eye to enable us to see objects, are discussed. (Interview cards and survey used, additional student responses, and percentage of correct survey responses are included in appendices). (JN)

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LEARNING IN SCIENCE PROJECT

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LIGHT

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WORKING PAPER No. 23

In our view successful science teaching requires an appreciation not only of the scientists' view of the world, but also an appreciation of the language, the beliefs and the expectations which children bring with them to science classes. This working paper has developed from a study carried out in the in-depth phase of the Learning in Science Project and is one of a series of papers which explores aspects of Children's Science (see Working Paper No. 14). It is our hope that these papers portray children's views of the world and meanings for words in a way which will be useful to teachers and to curriculum developers.

In the action-research phase of the project it is our intention to attempt to build practical and useful teaching strategies based on the findings of the in-depth phase of the project. For this reason we are actively seeking comments on the findings we have detailed, and seeking information on the variety of ways teachers develop ideas associated with the topic under focus in this paper.

We would be grateful if comment and/or information could be forwarded to

The Learning in Science Project.
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LIGHT

A working paper of the Learning in Science Project

Beverley Stead and Roger Osborne

December 1980

1. INTRODUCTION

This study is one of a series of investigations undertaken by the Learning in Science Project to find out about children's meanings for words and children's views of the world in which they live. In this study children's views about aspects of light were investigated by showing children, in an individual interview situation, line drawings which represented various sources of light - candle, sun, torch, heater and television - and various relectors of light - moon, painting, mirror, movie screen and rainbow (see Figure 1). The interviews were structured in the sense that each student was shown the same sequence of cards and asked the same questions. The first question asked with each card was:

> "Does the (candle) make light?" followed by "Why do you say that?"

For each card, further questions explored the students' views about what happens to the light. The question(s) were:

> "What happens to the light the (candle) makes?" supplemented, where appropriate, by "Does it stay around the (candle) or move out?" "About how far would the light from the (candle) go?" "Would it go as far as the person?"

For each card a final question explored the students' views of how people see things.

> "How is it that the person is able to see the (candle)?"

As the interview progressed, further questions were asked and others explained more fully, modified or omited, as appropriate, in order to gain a clearer understanding of each student's concept of light and its properties.

The interviews were conducted at five different schools in empty classrooms, the sick room, or the staffroom, depending on what was available. They were tape-recorded, with the permission of the interviewee, and the tapes were then transcribed to obtain a written record of the interviews for the collation of results.

The sample consisted of thirty-six students selected from five schools. Teachers of the various classes were asked to select children of average ability for the investigation. There were equal number of boys and girls, and both European and Polynesian students. The sample composition was:

10 Standard 3 students	(10 years old approximately)	000-009[1]
9 Form 1 students	(11 years old approximately)	100-108
7 Form 3 students	(13 years old approximately)	300-306
10 Form 5 students	(15 years old approximately)	500-509

2. DOES THE OBJECT MAKE LIGHT?

In this section we consider students' answers to the question

"Does the (candle) make light?"

(a) Ideas about reflection and omission of light

Many students appreciated that some objects reflected light rather than produced it.

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1 These numbers are used to identify each student and are referred to later in the paper.

"No, it only reflects light."
(mirror, 001, 108, 302, 500, 503, 505, 507)

"No, not unless light's reflected on to it".
(painting, 300, 500, 502)

"No, it just reflects light from the sun."
(moon 001, 108, 304, 305, 500, 507)

"No, the sun reflects through the rainbow."
(rainbow, 300, 304, 501)

The following student, apart from the incorrect use of the word 'glow', also appeared to have a good understanding from a scientific perspective.

> "No, not really the sun reflects onto the moon .. it makes the moon glow and then it comes down to earth." (moon, 001)

While the above ideas appear quite respectable from a scientific point of view, it really depends on what students mean by reflect. Students' meaning of 'reflect' may not always be a scientific one. For example,

> "(What do you mean by the word reflection?) Something you look at, and it does whatever you do. If you jump up and down, it will jump up and down too." (mirror, 104, 103, 105)

> "(Does the mirror make light?) No, not really ..... it really only reflects ... ('reflects' - What does that mean to you?) ... the sun goes into it, it sees itself in the mirror, its reflection." (mirror, 004)

> "(Could you describe what you mean by 'reflect'?) It (the light) bounces back." (mirror, 302)

Other students appeared to appreciate, or at least implied, that an energy source was required to produce light - another quite respectable idea from a scientific viewpoint.

> "Yes, it burns and gives off ... there's a chemical reaction." (candle, 501)

"There will be energy given off in the coils in it. Gives off some light ... not all that much."
(heater, 501)

"Yes, a certain amount. It's more heat though ... from the electric watts, from the heat."
(heater, 509)

"Yes because when you put batteries in it, that's what makes light in the bulb."
(torch, 006, 002, 007, 101, 104, 108, 302, 507, 509)

A few had somewhat similar views although their exact reasoning was somewhat more obscure.

"Yes, not the actual torch ... the bulb."
(torch, 001, 107)

"Well, because the electricity ... well thats' a different sort of power ... electricity does give off lights of certain colour ... it has kinetic energy and heat." (heater, 505)

"Yes, the radiation from the screen and it gives off a bit. (What do you mean by radiation?) The energy coming, being transmitted and it's radio-active ...its not dangerous like uranium but it's got a bit of ..." (television, 501)

These latter comments show some rather confused ideas from a scientific point of view.

(b) Egocentric and human centred viewpoints

As we have identified in other studies (for example, in the Working Papers No. 18, Force; No. 19, Friction; and No. 20, Gravity) students frequently refer to human experiences and provide answers that are human centred:

"No, it shows you your reflection." (mirror, 103)

"Yes, if you're right up the front, it can light you up." (movie screen, 102)

"Yes, because you can see it and there's little particles on it ... dust and that."
(movie screen, 105)

"At night you can see the moon ... sometimes you can see it during the day but it's not very bright." (moon, 502)

"Yes, you can see the screen. It lights up so you can see whats on it." (television, 100)

"Yes, you can see people moving on the screen. Without light you couldn't see them moving around." (television, 502)

"If you were on the side you'd see all the light coming out from the profile." (television, 005)

"Not really. You've got to have ... kind of light to be able to see yourself in the mirror." (mirror, 101)

"Yes, because whenever you look at the sun, you can get sore eyes." (sun, 007, 302)

(c) "If you can't see it in the dark, it doesn't make light."

We have often been told by children in previous studies (for example, Working Paper No. 19, Friction) that if something can't be detected by the senses, it doesn't exist. In the case of sources versus reflectors of light, whether or not the object can be seen in the dark provides a rough, but not unreasonable, basis for categorization. Students did refer to this:

"A bit, not much. Mostly heat. You put it in a dark room though, you'd just put a little glow out." (heater, 301)

"Yes, because when you turn off the lights at night, you can still see the television." (television, 101, 305)

"If you take the painting into the dark ... it won't make light." (painting, 001

"No, not really, because you can't see it in the dark ... you need light to be able to see it." (rainbow, 101, 108, 306)

"Yes, if it's dark you ... it doesn't make light. It's sunny or if you've got the light on, it kind of shines." (mirror, 002)

"Yes, because if you're in the dark and it lights up, then it's light in the room. You can see things." (candle, 105, 106, 300. 306, 500, 503, 506)

"Yes, because if you are in the dark and use a torch you can easily see other things." (torch, 000, 105, 300, 303, 306, 504, 505)

(d) Everyday language

Two words used frequently were 'shine' and 'glow'. According to the dictionary (Oxford) 'shine' is to emit or reflect light while 'glow' means to give out light and also has the connotations of heat energy as well.

The word 'glow' was used appropriately by some, even though the comments indicate a certain amount of circular reasoning:

"(Yes), because it glows." (candle, 104, 302, 305)

"Yes, it is glowing." (heater, 005, 007, 503)

"Yes, it's a glowing mass of gases." (sun, 005, 006, 101, 107, 301)

"No, it wouldn't make light. If it glowed like (fire) it would." (painting, 101)

Others used the word 'glow' in a somewhat different way:

"No, it's just a glow." (painting, 102)

"No, it glows ... it's light in itself but it doesn't make light on earth." (moon, 303)

"Oh sometimes it can make light and glows." (painting, 007)

"No, not really, it's designed to give off heat, not light. It's got the red ... that makes the heat. In the dark I suppose it gives off a little glow but it doesn't really give off light." (heater, 506)

"No, the rainbow doesn't shine. You can look at it without having to squint your eyes ... you look at it and it's just a glow."
(rainbow, 102)

The word 'shine' was used according to the dictionary definition by a few students. For example:

"No, because the painting doesn't really glow out. (It) might shine when the sun comes out but ...."
(painting, 000)

"No, it isn't shining, and it isn't hot, it doesn't glow, it stays in one place."
(painting, 005)

Other answers made it less clear just what the person thought;

"I think so ... because it shines." (mirror, 305)

"No, it's meant for making you warm ... and it doesn't have any light ... it doesn't shine up."
(heater, 002, 102)

"Yes, it shines up against the black sky."
(moon, 002, 004)

(e) Commonsense answers

Finally other answers were provided which, to the respondent, were perfectly adequate answers which needed no further explanation in their view:

"Yes because it's got heat." (candle, 304, 504)

"Yes, it's got fire ... a flame."
(candle, 000, 002, 003, 004, 005, 006, 100, 101, 102, 103, 301, 305, 505, 509)

"Yes, it's big and bright." (sun, 002, 003)

"Yes, all the light around it. It lights up the whole world."
(sun, 103, 104, 105, 106, 303, 305, 502, 505)

3. DOES LIGHT TRAVEL AND IF SO HOW FAR?

The students had varying views about whether or not light travels and how far it travels. For example, with the instance of the electric heater, some students had a concept close to the scientific one, that light travels as far as it can go.

> "It reflects off the shiny backing on the heater ... about 20 feet." (507)

Others had a concept that light travels only a small distance.

> "It wouldn't go very far." (304)
>
> "Only a few feet." (300)
>
> "It only goes a short way." (005)

Others said the light did not travel away from the source at all.

> "It stays on the heater." (003, 004, 006, 301)

Similar results were obtained with the instances of reflectors. For example, with the movie screen,

> "It gets (to) the screen and it's reflected everywhere." (506, 509)
>
> "It comes out a certain distance depending on the brightness of the movie. But it stops after awhile, it doesn't go right to the back of the hall." (102)
>
> "It stays on the screen." (006, 007, 105)

Over all the instances, the students could be categorised into four groups on the basis of their answer to the question "What happens to light?" and subsequent questioning, if appropriate, as to how far the light travelled. The four groups and typical student answers, as categorised into these groups, are detailed in Figure 2.

The distance the students considered the light to travel sometimes depended on the size of the source. For example, many students (005, 104, 105, 106, 303, 304, 500, 501, 503, 504, 505, 506, 507, 509) said the light from the sun travelled down to the earth. This source is large enough for light of a perceivable intensity to be on the earth. Only a few students (100, 104, 105, 106, 305) said the light from the candle would travel any distance.

Students indicated that the distance the light travelled would depend on whether it was day or night.

> "In a dark room it would light up the whole room." (candle, 100, 104, 105, 106)

Some students stated that the person illustrated on the card, would be able to see the object but the light from the object would not travel as far as the person.

> "He could see it, and feel it, but the light wouldn't touch him." (heater, 005, 104, 304, 500, 502)
>
> "He can see it but the light doesn't reach him." (painting, 304)
>
> "It wouldn't reach him but he could see the TV." (television, 104, 305, 506)
>
> "They could see the picture and that, but I don't think it (the light) would reach them." (movie screen, 104)

The notion of intensity was illustrated in the answers of some students.

> "It only goes up to a certain distance and then you get a dimmer light, it's getting dimmer, then dark." (candle, 001, 507)
>
> "It sort of fades away." (torch, 105, 108, 304, 305, 507)

"It just comes out and fades." (heater, 302)

"It just fades away about two or three feet away from the TV." (television, 001, 304, 506)

"... As it gets further away from the moon, it gets duller." (mirror, 001, 108)

"It fades away into the room." (painting, 304)

In summary, some students in the sample did not see the light as travelling at all and for others the distance travelled varied between one metre and an infinite distance. The distance the light travelled was seen to vary with the instances. Students of all ages in the sample, could be found in each category.

As a follow up study, and to obtain a more quantitative appreciation of student views about whether, and how far, light travels, a multiple choice survey was constructed, where the possible alternatives (A,B,C and D) were composed to match the four major categories established from the interview results.

The questions centred on the various sources (candle, heater, light and TV) in both the day and the night, and two reflectors (movie screen, mirror). The survey was identical to that illustrated in the Appendix except the drawings were less detailed (more like those in Figure 1) and option D of each question read "comes out until something else stops it."

The survey was administered to 144 Form 2 students, representing 5 classes in three intermediate schools in the Hamilton area. None of these students had studied light in the previous twelve months.

The percentage of students (N=144) choosing each category is set out in Figure 3. It will be noted that there is a higher percentage of students choosing answers "A", "B" and "C" than the scientifically correct answer "D". The percentage of students choosing each category varies between the day and night situations.

In addition to the above results for Form 2 students who had not been taught light, similar results were obtained for the 32 Form 2 students who had in fact covered the unit of work on light.

Discussion with further students about the survey identified a possible deficiency in the questions, despite our pre-testing. It appeared that a few students interpreted D, "comes out until something stops it.", not as the light travelling until it was absorbed or reflected, but as the candle being blown out or the heater being turned off. This problem led to a revision of the survey (final format as in the Appendix). The pictures were altered to give more detail as to whether it was day or night and answer D was changed to "comes out until it hits something."

The survey was sent to volunteer teachers in widely spread New Zealand schools. It was administered to 235 Form 3 students who had recently studied a unit on light. The percentage of students choosing each category is provided in Figure 4 and the responses are basically similar to those obtained with the first test. The results strongly suggest that the Form 3 students, like the Form 2 students, tended to respond in a different way to daytime and night-time instances. Again, at least half the sample said the light did not travel away from the candle, heater, light, and TV (the sources) during the day, and a higher percentage chose answer "D" for the source during the night than during the day.

Unlike the results of the Form 2 students who had not had tuition on light, the results of the Form 3 sample indicate that they saw a difference between the movie screen and the mirror. Perhaps the laboratory work on mirrors had changed their concept of this type of reflector.

In summary despite some methodological problems with the survey which we will not explore here [1], this minor quantitative study indicated clearly that Form 3 students who had been taught light, had views very similar to Form 2 students who had not been taught light.

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1 Methodological issues are explored more fully in a published paper on aspects of this work; Stead B.F. and Osborne R.J. Exploring science students concepts of light Australian Science Teachers Journal 26(3) (in press)

4. HOW IS IT THAT THE PERSON IS ABLE TO SEE THE (CANDLE)?

Student responses to the above question can be classified into 7 major groups:

(a) The colour, brightness, and contrast

"Because it's on a background and it's black and white and he can see it because of his eyes." (candle, 004)

"It stands up against the dark sky and it's bright." (candle, 002, 300, 502, 504)

"The sun reflects on the moon and that makes the moon bright and then you'd be able to see it because of the brightness of the moon." (moon, 003, 302)

"The light on the elements is bright so you can see them." (heater, 301)

"It's just the colour of it." (painting, 100, 102, 108)

"The bright red, it's bright. It doesn't shine but it's a glow and just catches a person's eye." (painting, 102, 300, 305, 505)

"It can stand out in the dark." (movie screen, 108)

"It's the brightest part of the picture theatre." (movie screen, 507)

"The bright colours." (rainbow, 000, 002, 100, 102, 500)

(b) The light only

"The light." (candle, 003, 301)

"It's light. The moon is light." (moon, 500)

"Because the torch gives light." (torch, 003, 100, 108, 300, 302)

"The person could see the heater but anyone standing by the heater couldn't see the person ... I think that the light is just there but doesn't shine bright in the whole room." (heater, 105)

"The light provided by the sun... he'd be able to see it ... it shows up the painting." (painting, 106, 301)

"Because it was day and it might be light and they could see it." (mirror, 004, 103)

"They can see the screen because of the light the screen's making to show the pictures." (movie screen, 003, 004, 100, 102, 103)

"By the light it gives off." (rainbow, 302)

"Because it's daytime and the sun is shining through on bits of rain. It lights that up and you can see it because it is reflecting something on the ground." (rainbow, 306)

(c) The Eyes only

"His eyes." (candle, 000, 101, 102, 103, 302, 500, 509; sun, 000, 101, 103, 302, 502)

"He uses his eyes." (heater, 500, 509)

"His eyes help him." (painting, 002, 507)

"He can see it with his eyes." (television, 000, 004)

(d) The Light and the Eyes

"With his eyes and because the sun is shining on it." (sun, 100)

"The light enables the person to see the torch with his eyes." (torch, 504)

You look at it in the daytime ... because in the daytime the sun's shining on it ... the sunshine or light helps put the colour into your eyes." (painting, 001)

"Because of your eyes and the light that's coming in through the windows and hits the painting and you'd be able to see it because there is light." (painting, 005, 101, 302)

"Through the eye and they have to have a bit of light." (mirror, 101)

(e) Actively Looking

"Watching it." (television, 100)

"Yes, because the people are moving around and your eyes can watch them." (television, 002)

"It reflects so that you can see it ... you're sitting under the light itself and the eyes can focus on to the screen and you can see the objects that's moving." (movie screen, 500)

"It (the light) hits our eyes, well we look at it and we just see it." (movie screen, 506)

"By looking at it." (rainbow, 509)

This category is further supported by the views documented in Section 3, that the person would be able to see the object even though the light from the object didn't reach the person.

(f) The light comes out of the eye

"When the light hits the eye, it turns the object upside down, then it goes up, comes back again and is reflected back on the object. (So the light is coming out of the eye?) Yes." (heater, 501)

"The image goes from them to the mirror and back to them." (mirror, 302)

"You look in the mirror ... your sight takes a picture of it ... bounces off the mirror ... comes back." (mirror, 301)

(g) The light is travelling into the eyes

"It (the light) goes through the eyes, then through the nerves, through to a certain part of the brain." (candle, 001)

"The light which is reflected ... be able to see it ... in his lens he would reflect it ... reflect into his eyes ... and it would be transferred to his optic nerve and he would be able to see through that." (candle, 502)

"His eye ... it goes in upside down and it hits sort of mirrors to turn it up the right way." (candle, 503)

"As the person's looking at it ... the light's travelling to his eyes." (television, 300)

"Well, he looks at the bright coils in the heater and can just see it. You look at it. Reflects into your eyes, you can see it." (heater, 507)

"He looks at it ... and the light reflects off the TV and it goes into the back of the eye."
(television, 507)

"It (the light) goes into your eyes so that you can see it." (painting, 503)

The above comments show that for all but one of the seven categories, both Standard 3 and Form 5 responses can be found. The comments also indicate that very few students indeed have clear understanding that light must travel into the eye to enable us to see objects.

5. Summary

Children do have views about those aspects of light that were investigated in this study.

Most children had a reasonable idea that the sources of light they were shown (e.g. candle, sun, torch, heater and television) did 'make' light. However, for a few children, some of the reflectors (painting, movie screen, mirror, rainbow, and moon) were also considered to make light. The reasons given for why an object was considered to make light varied widely, while any one student gave a variety of reasons depending on the object being considered at that time.

With regard to the transmission of light, some students did not see light as travelling at all, while for others the distance varied from a few millimetres to an infinite distance. The distance the light travelled, depended on the card being considered and for a sizeable group of children it depended on whether it was daytime or night time. In our views, these findings suggest that many young students tend to consider light is only present if there is sufficient light for observable effects of the light to be noticeable e.g. the flickering illumination from a candle on a wall.

With regard to the question, "How is it that we see objects", few students could give a scientifically acceptable answer. A number of children held the notion that we see objects because we actively look at them or because light comes out of our eye.

Concepts that differed from the scientifically accepted one, were held by students at all age groups. For example, the following answers were given to the questions about the candle:

"Does it make light?"
S. "Yes, it's got fire ... a flame." (000, 002, 003, 004, 005, 100, 101, 102, 103, 301, 305, 505, 509)

I. "What happens to the light?"
S. "It stays close to the candle." (000, 002, 003, 004, 006, 007, 103, 301, 504)

I. "How is it that the person can see the candle?"
S. "It stands up against the dark sky and it's bright." (002, 004, 300, 502, 504)

Scientifically acceptable answers and explanations were given by students in different age groups, but there were fewer examples. For example, the following answers were given to the question about a candle:

I. "Does it make light?"
S. "Yes, because if you're in the dark and it's light in the room. You can see things." (105, 506)

I. "What happens to that light?"
S. "Well, it goes out in rays and just if ... there's an object or something, it will touch it and it will shine, and if it's glass it will ricochet somewhere else." (005, 506)

I. "How is it that the person can see the candle?"
S. "It (the light) goes through the eyes, then through to the nerves to a certain part of the brain and then the brain does the work ... so you can see." (001, 502)

Implications for teaching

> "Oh most of the time we were just drawing ray diagrams of what happened rather than seeing how it happened. I had great trouble understanding reflection, refraction and things ... anyway who wants to know what sort of lens produces what sort of light?" (ex-pupil)

The above quote made to us by a second year Teachers' College student during the exploratory phase of the Project, is now much more meaningful to us. If children do not appreciate that light travels, that some objects simply reflect light rather than produce it, and that light must enter the eye to enable us to see, then much of what we teach about light must be, at the least, very confusing. We may well need to reconsider what prior knowledge students bring with them to lessons on light.

(a) Before teaching that light travels in a straight line we may first need to teach that light travels. That how far it travels does not depend on whether it is daytime or night time even though it may appear to travel further at night.

(b) Before teaching ideas about reflection and refraction we may need to teach about sources, reflectors and how it is that we are able to see things.

(c) We may need to reconsider the appropriateness of talking about radiant energy. Heat and light are different things to children, detected by different parts of the body. However, there is currently confusion between the two quantities.

I. "Does a candle make light?"
S. "Yes."
I. "Why do you say that?"
S. "Because its got heat and heat makes light."
(candle, 502 505, 508)

I. "Does anything happen to that light once it's made?"
S. "Just gives heat."

I. "The actual light gives the heat?"
S. "Yes." (heater, 000, 002, 006, 100, 305, 500)

I. "Are light and heat the same thing or different?"
S. "Sort of the same, in a way and different in other ways. Well they're both the same because they both give off heat. Light and heat are sort of the same thing, and yet, light sort of glows and heat is warm."
(heater, 000, 002, 3[illegible]

I. "What happens to the light that the sun's making?"
S. "Gives out heat." (sun, 006)

I. "Does the sun make light?"
S. "Yes"
I. "Why do you say that?"
S. "... the sun makes you warm and other light makes you warm." (sun, 007, 304, 501)

Perhaps we should conclude with a comment recently made to us in a conversation we had with a senior intermediate teacher on the topic of light.

> "I don't think anywhere in these units does anyone ask us to develop the concept of light per se as you have outlined it. The syllabus hardly says that you have to develop the concept of light ... it is hardly mentioned (but we make assumptions?) yes."

Do we make unjustified assumptions when we teach about light? If so, then we need to consider what we do and how we do it.

Acknowledgements

We would like to thank Robyn Boe for her sharing of the lengthy task of interviewing and transcribing the tapes.

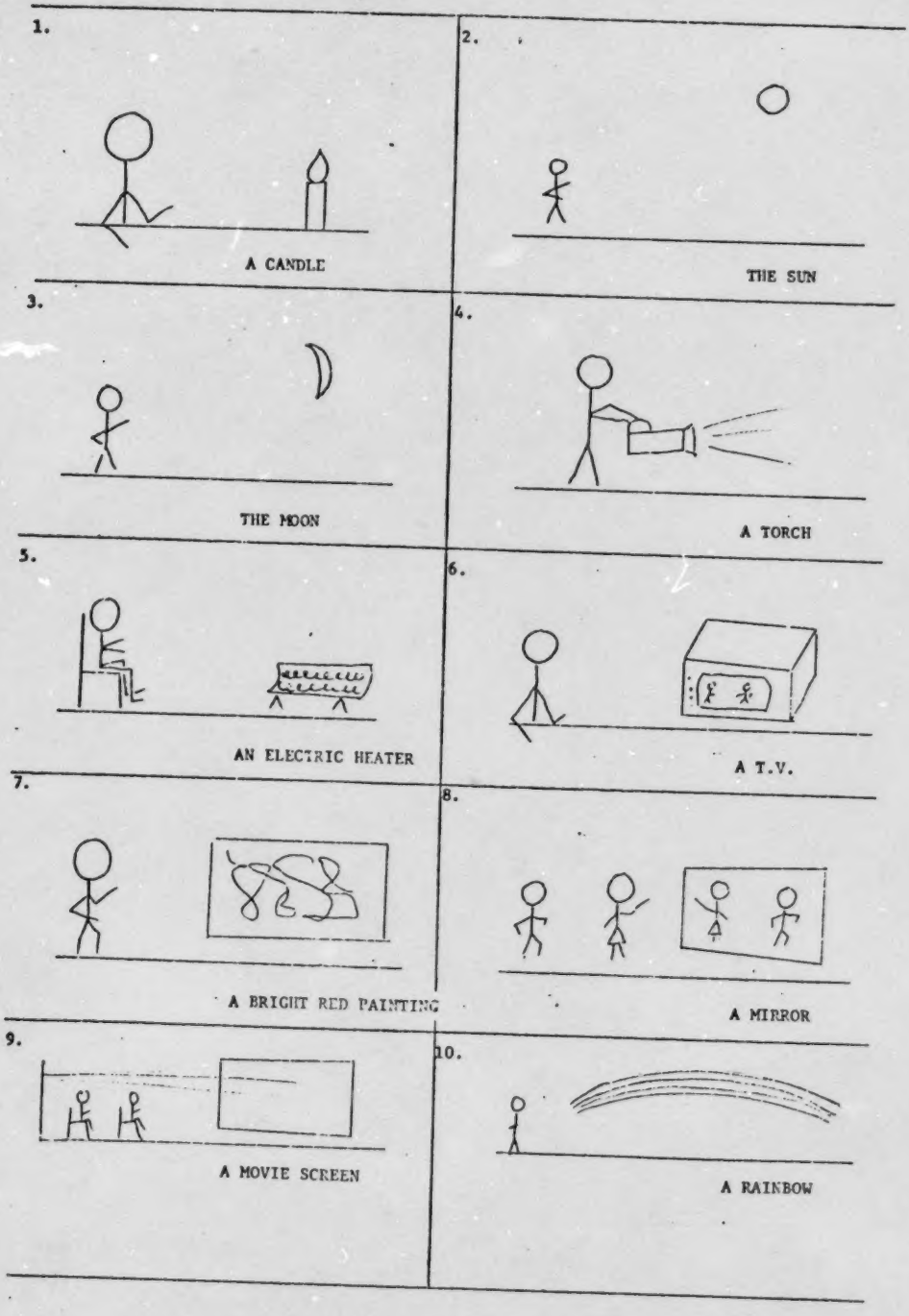


FIGURE 1 : The cards illustrating the five sources and five reflectors used in the interviews, in the order they were presented.

(a) The Light stays on or very close to the object

"Stays there." (candle, 000, 002, 003, 004, 006, 007, 103, 301, 504)
"It stays around." (sun, 101)
"Stays around it." (moon, 300)
"It stays in front of the torch." (torch, 004, 100, 101)
"It stays on the heater." (heater, 003, 004, 006, 301)
"It stays around the painting." (painting, 006, 007, 305)
"It stays on the TV." (television, 002, 004)
"It just stays around the mirror." (mirror, 104)
"It stays on the screen." (movie screen, 006, 007, 105)

(b) The Light comes out about a foot

"About an inch." (candle, 305)
"It won't go far." (torch, 306, 509)
"Not very much, about less than a foot." (heater, 002)
"Not very far, just around the TV." (television, 305)
"Maybe a foot or so away from the TV." (television, 505)
"Only a short distance." (mirror, 006)
"It stays around the mirror, a couple of feet." (mirror, 305)

(c) The Light comes out a metre or more, or to the person watching

"As far as the person." (candle, 506)
"Between five and ten feet." (candle, 304)
"A couple of feet." (candle, 508, 509)
"Not far, about half the size of this room." (heater, 106)
"Comes out a little way ... just about to the person." (television, 000, 007, 300)
"Not very far, just a couple of feet or so." (television, 506)
"It comes out a certain distance depending on the brightness of the movie. But it stops after awhile, it doesn't go right to the back of the hall." (movie screen, 102)

(d) The Light travels a Long Distance

"In a dark room, it would light up the whole room." (candle, 100, 104, 105, 106)
"It bounces off the walls and goes all over the place." (candle, 306)
"It travels ... to the earth." (sun, 005, 104, 105, 106, 303, 304, 500, 501, 502, 503, 504, 505, 506, 507, 509)
"The light spreads out over the space ... in all directions ... as far as the person." (sun, 301, 302, 306)
"It comes down to earth." (moon, 006, 104, 105, 106, 302, 303, 304, 306)
"The light spreads out as far as it's energy can go." (torch, 302, 506)
"It goes out into the room ... quite a way." (television, 108)
"Just goes about couple of metres ... and then stops. Gets dimmer and dimmer ... about from here up to the road. (quite a long way) Yes." (mirror, 005)
"It gets the screen and it's reflected everywhere." (movie screen, 506, 509)
"It goes ... all over the room." (television, 302, 306)

FIGURE 2. Typical student responses 4132A

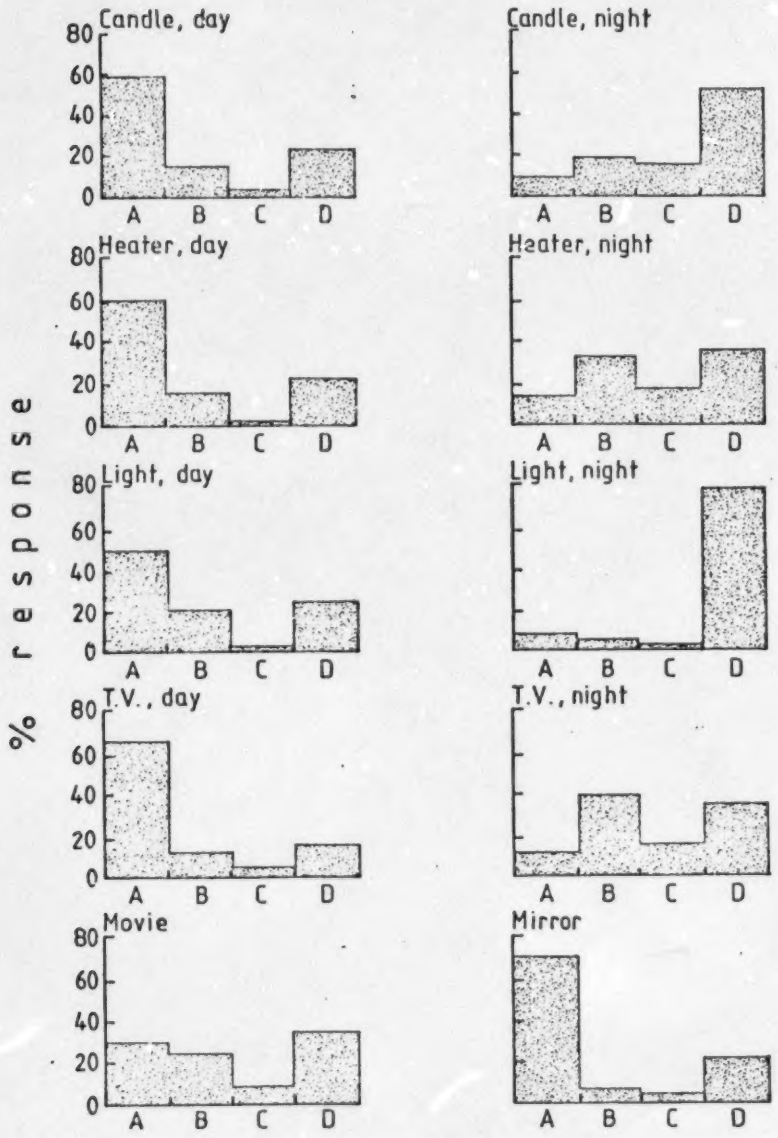


FIGURE 3. The Frequency of Form 2 Students (who had not studied light) choosing each category. (N=144).

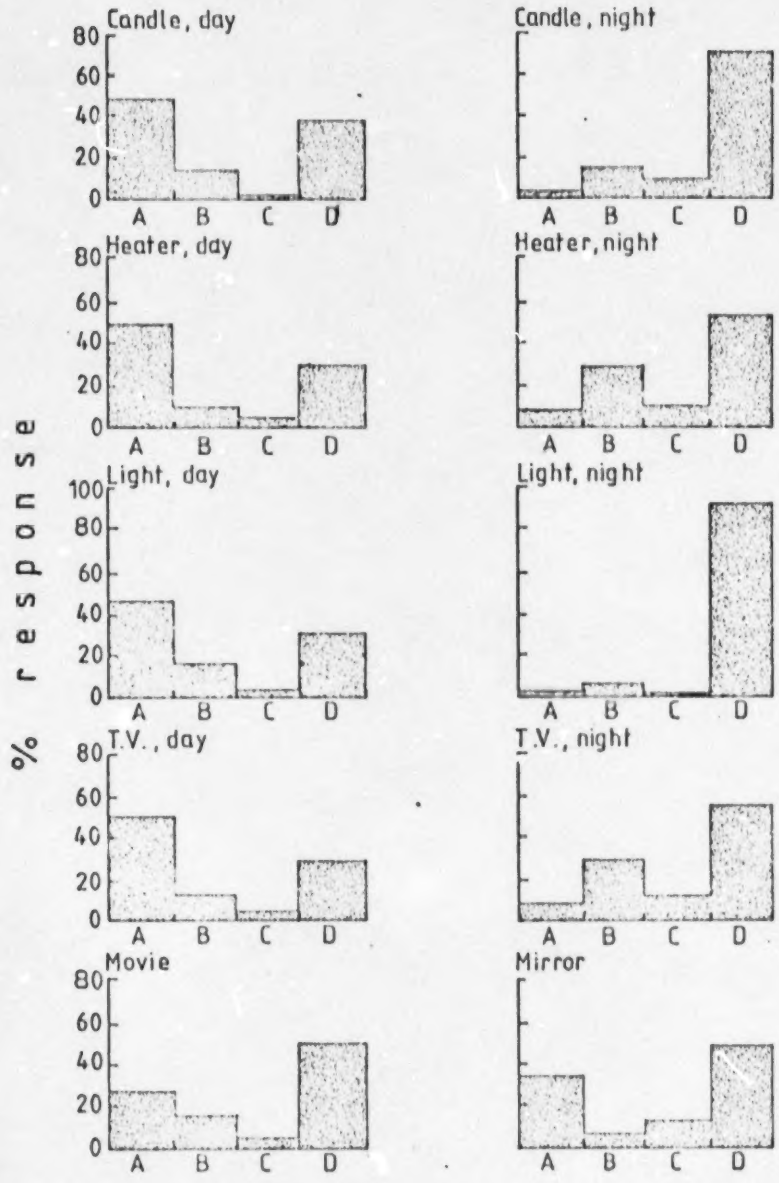


FIGURE 4. The Percentage of Form 3 students (who had studied light) choosing each category (N=235).

University of Waikato

Appendix

LEARNING IN SCIENCE PROJECT
LIGHT

Name _____

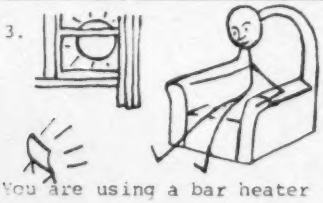
School _____

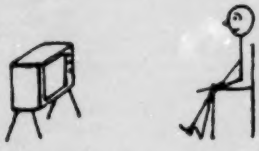
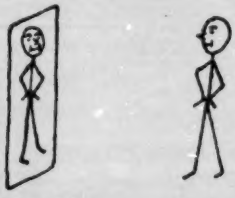
Class _____

For each question there are four possible answers.

Choose the one you think BEST answers the question.

Place a tick in the column to show which answer you think is best.

		Answer column	
1. You are watching a candle burning during the day.	The light from the candle: A: stays on the candle. B: comes out about halfway towards you. C: comes out as far as you but no further. D: comes out until it hits something.	 A B C D	11 1 2 3 4
2. There is a power cut during the night. You are using a candle.	The light from the candle: A: stays on the candle. B: comes out about halfway towards you. C: comes out as far as you but no further. D: comes out until it hits something.	 A B C D	12 1 2 3 4
3.  You are using a bar heater during the day.	The light from the heater: A: stays on the heater. B: comes out about halfway towards you. C: comes out as far as you but no further. D: comes out until it hits something.	 A B C D	13 1 2 3 4
4. You are using a bar heater at night with all the room lights out.	The light from the heater: A: stays on the heater. B: comes out about halfway towards you. C: comes out as far as you but no further. D: comes out until it hits something.	 A B C D	14 1 2 3 4

		Answer column	
5. You are looking at a movie screen.	The light from the movie screen: A: stays on the movie screen. B: comes out about halfway towards you. C: comes out as far as you but no further. D: comes out until it hits something.	 A B C D	15 1 2 3 4
6. You have the light on during the day.	The light from the light bulb: A: stays on the light bulb. B: comes out about halfway towards you. C: comes out as far as you but no further. D: comes out until it hits something.	 A B C D	16 1 2 3 4
7. You have the light on during the night.	The light from the light bulb: A: stays on the light bulb. B: comes out about halfway towards you. C: comes out as far as you but no further. D: comes out until it hits something.	 A B C D	17 1 2 3 4
8.  You are watching a television programme during the day.	The light from the television: A: stays on the television. B: comes out about halfway towards you. C: comes out as far as you but no further. D: comes out until it hits something.	 A B C D	18 1 2 3 4
9. You are watching a television programme at night with all the room lights out.	The light from the television: A: stays on the television. B: comes out about halfway towards you. C: comes out as far as you but no further. D: comes out until it hits something.	 A B C D	19 1 2 3 4
10.  You are looking at yourself in the mirror.	The light from the mirror: A: stays on the mirror. B: comes out about halfway towards you. C: comes out as far as you but no further. D: comes out until it hits something.	 A B C D	20 1 2 3 4